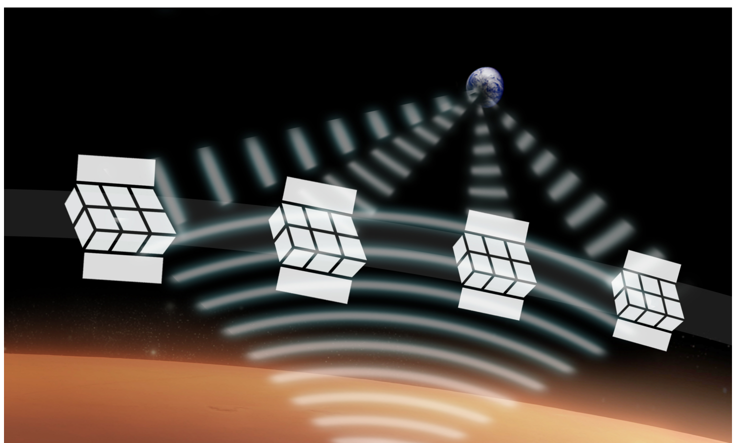
Mars CubeSat/NanoSat Workshop

Application of Mars CubeSat Constellations to Atmospheric and Interior Structure Investigations


Artist rendition of JPL concept for Mars mission with Four CubeSats

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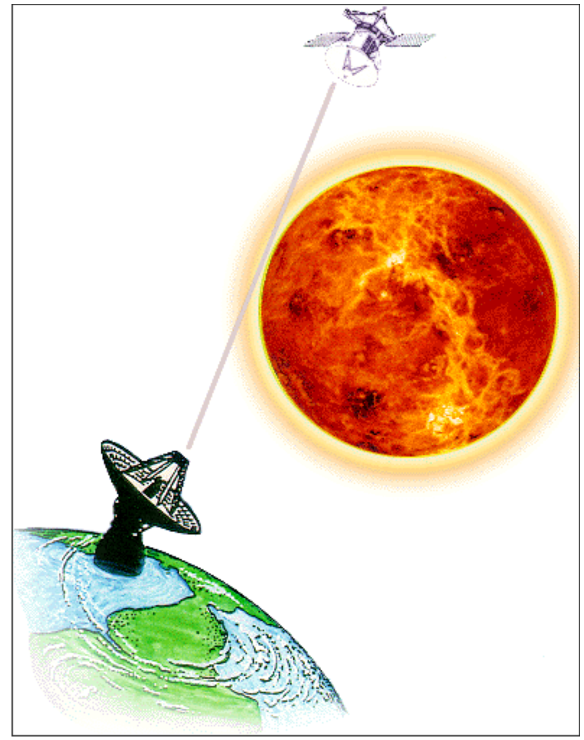
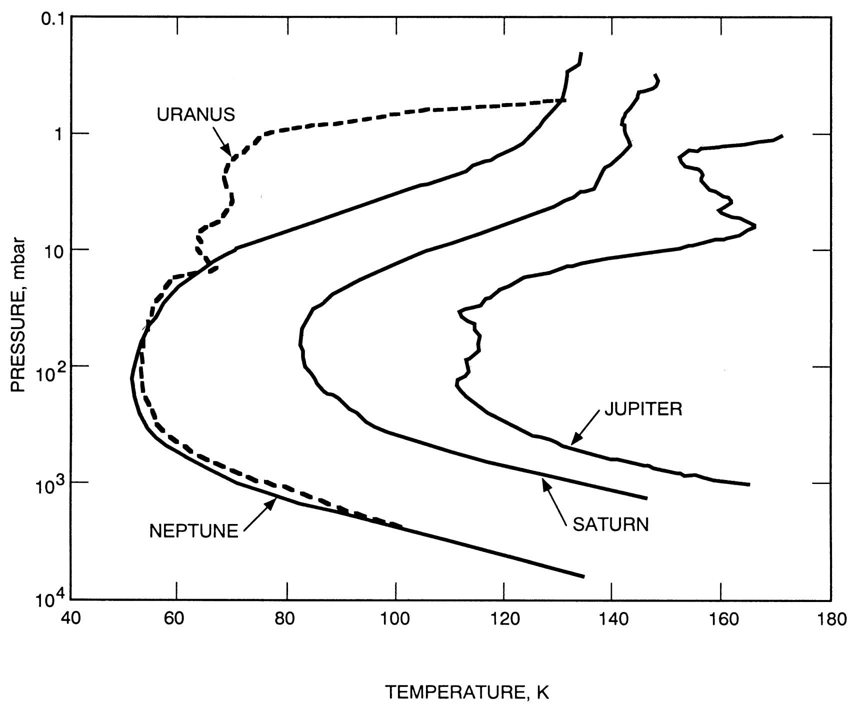
Atmospheric Radio Occultations

- Propagation and Gravitation branches of Radio Science rely on high quality radio links between planetary missions and the DSN to investigate atmospheric density and temperature-pressure profiles
  - Via occultations and gravity field determination for deducing the interior structure
- Science from traditional single spacecraft can be significantly improved via configurations utilizing spacecraft-to-spacecraft links (aka crosslinks)

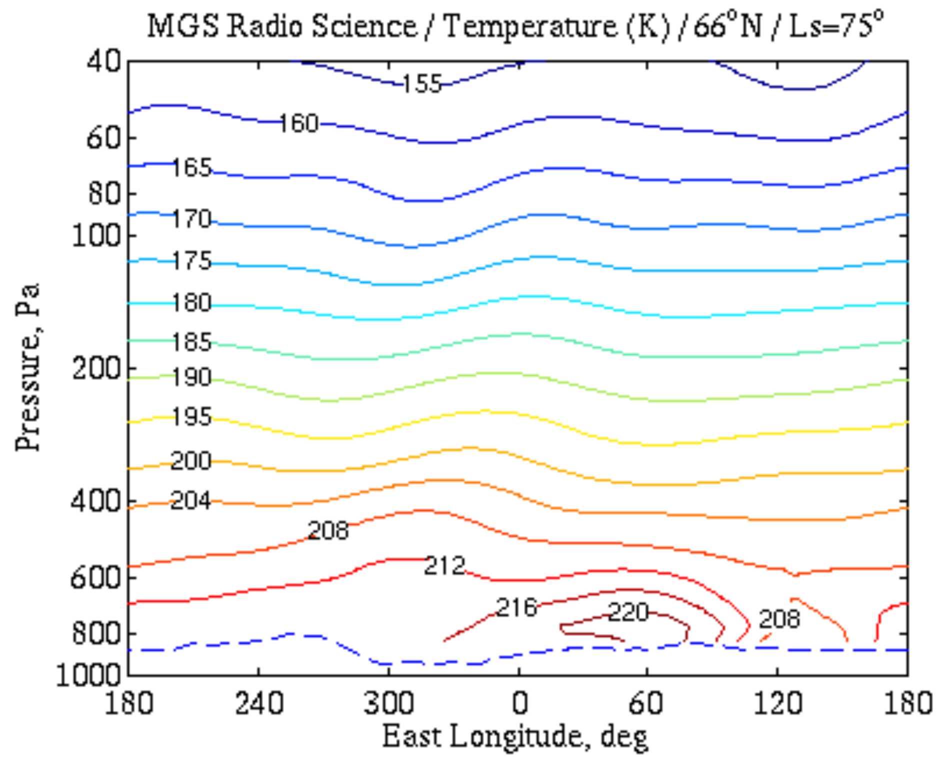


Classic Radio Science Results



Temperature profiles for the giant planets derived from radio occultation data acquired with the Voyager spacecraft (from Lindal, 1992)

Temperature-Pressures Profiles of the outer planets from Voyager single flybys



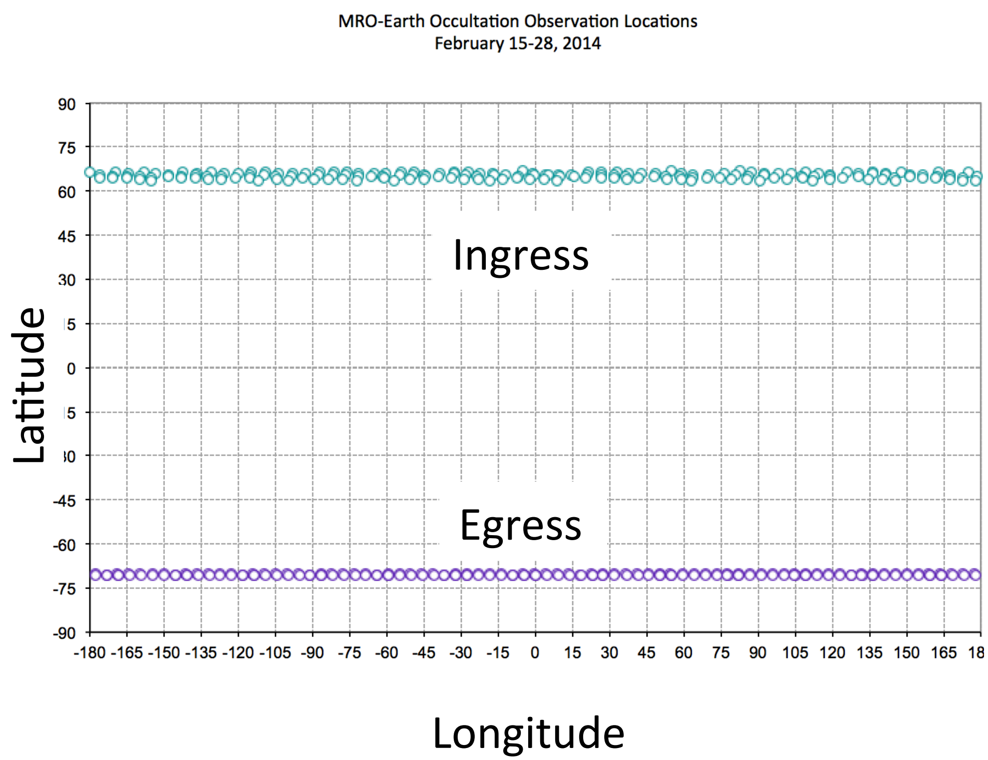
Ten years of radio occultations at Mars with MGS – selected Temperature-Pressures Profile

Multiple Spacecraft Occultations

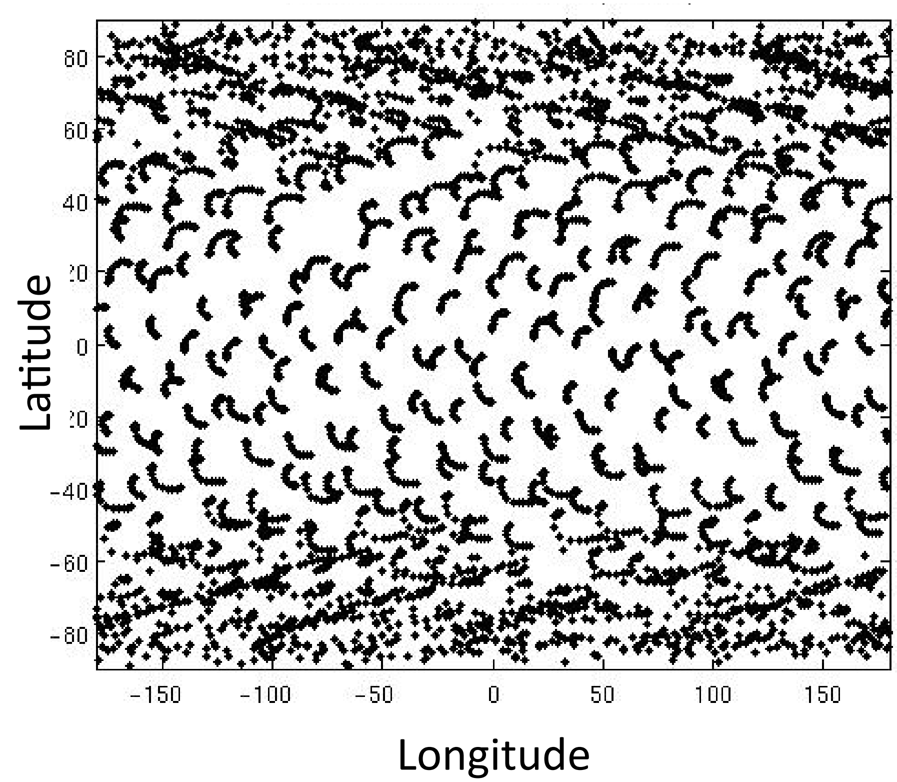
- Multiple spacecraft in orbit around Mars can achieve near-complete planetary coverage in a few weeks, as opposed to years with the traditional method

- Furthermore, the signal quality would be significantly improved due to the high signal-to-noise ratio of the links realized with proximity; a crosslink occultation demonstration was already carried out at UHF between Odyssey and MRO to sample the atmosphere and surface scattering

Planetary Coverage with Crosslinks



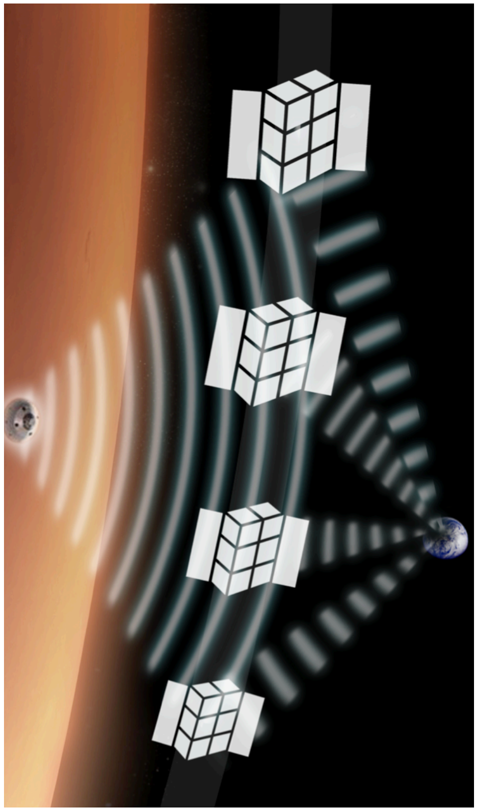
Mars coverage from two weeks of occultation with MRO – single spacecraft, traditional downlink (actual)



Mars coverage from two weeks of crosslink occultations – two spacecraft (simulated)

CubeSat Constellations

- Multiple large spacecraft are very costly
- Small constellation of cubesats can accomplish science objectives economically
- Technologies developing for science-class radio systems, ultra-stable oscillators, antennas of sufficient gain, and communications of observations telemetry
  - Multiple simultaneous wavelengths enhance science



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Gravity Field of Phobos

Phobos image from MRO from 6,800 km

Relative sizes of Phobos, Deimos, and Moon

Precision Doppler

- Constraining the interior structure of Phobos via gravity field measurement
  - Piece of puzzle for formation vs. capture theory
  - 2-way X-band Doppler tracking at close flyby distances
  - One over r-squared improvement in resolution with closer approach

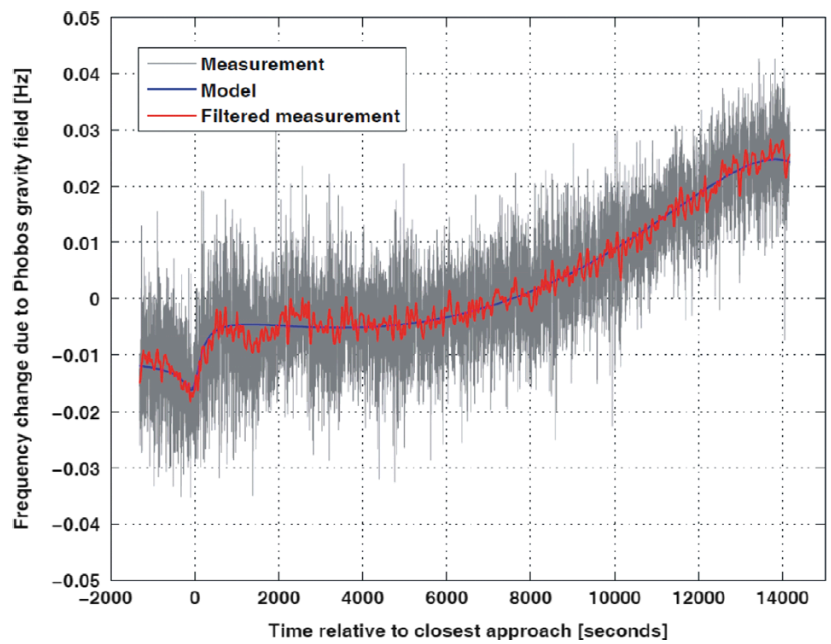

Fig. 3. Change in frequency residuals at *X*-band from about 1500 s before closest approach to 14,000 s after closest approach from the Mars Express 2006 flyby at a distance of 475 km. The grey data are the observed frequency residuals at one second time steps. The red solid line are the filtered observed data at a time step of 18 s. The blue solid line is the fit to the data which returns the pre-encounter bias and eventually the GM_{Ph}. Taken from Andert et al. (2010). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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Recent Results

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Phobos mass determination from the very close flyby of Mars Express in 2010

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A B S T R A C T

The global geophysical parameters $GM_{Ph} = (0.7072 \pm 0.0013) \times 10^{-3}$ km^3 s^{-2}, C_{20}, C_{22} and the bulk density $\langle\rho\rangle = (1862 \pm 30)$ kg/m³ have been determined from the closest Mars Express flyby at the Mars moon Phobos on 3rd March 2010 at a distance of 77 km. The second degree gravity field of Phobos (C_{20}, C_{22}) could not be solved for at sufficient accuracy. The low bulk density suggests a high porosity and an inhomogeneous mass distribution but the large errors of C_{20} and C_{22} are still consistent with a homogeneous as well as an inhomogeneous mass distribution. The modeling of the moon's interior by a randomly selected mass distribution of given porosity and water ice content but constrained by the observed GM_{Ph} and $\langle\rho\rangle$ let a simulated C_{20} decrease with increasing porosity and water ice content indicating an increasingly inhomogeneous mass distribution. The high porosity together with an inhomogeneous mass distribution would be evidence that Phobos accreted in orbit about Mars from a debris disk and is not a captured asteroid.

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Challenges & Objectives

- Challenge: Develop new instrument concepts for studying solar system atmosphere properties using smallsats and new JPL spacecraft radios being developed that provide much higher geographic and temporal density science data than previously possible
- Objectives
  - Determine science opportunities for new occultation science throughout the solar system
  - Determine technical requirements on spacecraft systems and configuration to achieve science goals
  - Design changes needed for science capability in new spacecraft radio systems